

Attorney Docket No. ISOT-020

## APPLICATION

**FOR UNITED STATES LETTERS PATENT**

— 1 —

## SPECIFICATION

23 TO ALL WHOM IT MAY CONCERN:

24

25 BE IT KNOWN THAT WE, **Donald D. Tilton**, a citizen of the United States,  
26 **Paul A. Knight**, a citizen of Canada, and **David H. Knaggs**, a citizen of the United  
27 States, have invented a new and useful liquid thermal management socket system of  
28 which the following is a specification:

1

2

3                   **Liquid Thermal Management Socket System**

4

5

6                   **CROSS REFERENCE TO RELATED APPLICATIONS**

7       Not applicable to this application.

8

9

10                  **STATEMENT REGARDING FEDERALLY**  
11                  **SPONSORED RESEARCH OR DEVELOPMENT**

12       Not applicable to this application.

13

14

15                  **BACKGROUND OF THE INVENTION**

16

17

18

19       **Field of the Invention**

20

21       The present invention relates generally to thermal management systems for  
22 electronic devices and more specifically it relates to a liquid thermal management  
23 socket system for thermally managing an electronic device in a socket.

24

25

26       **Description of the Related Art**

27

28       Electronic devices removably positioned within sockets have been in use for  
29 years. Sockets allow for efficient replacement and upgrading of electronic devices

1 (e.g. microprocessors). Figure 1b illustrates an exemplary socket unit (14) attached to  
2 a circuit board (12) (e.g. motherboard, expansion board) that has a plurality of socket  
3 receptacles (15) for receiving the device connectors of an electronic device. Figure 1a  
4 illustrates an exemplary configuration of an electronic device (16) coupled to a socket  
5 unit (14) with a heat sink (18) thermally coupled to the electronic device by a layer of  
6 thermal interface material (17) to allow for air cooling of the electronic device.

7

8       While conventional “air cooling” of electronic devices, air cooling is not  
9 desired an efficient method of thermally managing modern high-power electronics  
10 which have high thermal management requirements. In addition, air cooling is  
11 sometimes not capable of adequately thermally managing modern electronic devices  
12 with high heat flux areas resulting in reduced efficiency and possibly failure of the  
13 electronic device.

14

15       Liquid thermal management systems are the most promising technology for  
16 thermally managing modern electronic devices. Liquid cold plates, liquid immersion  
17 and spray cooling are the three most commonly utilized liquid thermal management  
18 systems. Liquid immersion and spray cooling are typically more efficient than liquid  
19 cold plates. Liquid immersion involves applying a dielectric liquid coolant directly over  
20 one or more electronic devices. Spray cooling involves spraying a dielectric liquid coolant  
21 onto one or more electronic devices. An exemplary spray cooling system is described in  
22 U.S. Patent No. 5,420,804 to Tilton et al., and is hereby incorporated by reference.  
23 Hence, it is desirable to utilize either liquid immersion or spray cooling in the thermal  
24 management of modern electronic devices.

25

26       While liquid thermal management systems have significant performance  
27 advantages over air cooled systems, there are some inherent problems. One of the  
28 problems with conventional liquid thermal management systems is that they sometimes  
29 require modifications by board manufacturers or electronic device manufacturers. A

1 further problem with conventional liquid thermal management systems is that they are  
2 not easily integrated within the form factor of standard air cooled sockets. Another  
3 problem with conventional liquid thermal management systems is that they do not have  
4 an industry form factor as air cooled systems do.

5

6 In these respects, the liquid thermal management socket system according to the  
7 present invention substantially departs from the conventional concepts and designs of  
8 the prior art, and in so doing provides an apparatus primarily developed for the  
9 purpose of thermally managing an electronic device in a socket.

10

11

1

2                   **BRIEF SUMMARY OF THE INVENTION**

3

4         In view of the foregoing disadvantages inherent in the known types of liquid  
5         thermal management systems now present in the prior art, the present invention  
6         provides a new liquid thermal management socket system construction wherein the  
7         same can be utilized for thermally managing an electronic device in a socket.

8

9         The general purpose of the present invention, which will be described  
10      subsequently in greater detail, is to provide a new liquid thermal management socket  
11      system that has many of the advantages of the liquid thermal management systems  
12      mentioned heretofore and many novel features that result in a new liquid thermal  
13      management socket system which is not anticipated, rendered obvious, suggested, or  
14      even implied by any of the prior art liquid thermal management systems, either alone  
15      or in any combination thereof.

16

17         To attain this, the present invention generally comprises a thermal management  
18      unit having a chamber for receiving one or more electronic devices, a plurality of first  
19      connectors within the thermal management unit for electrically coupling with the  
20      electronic device, and a plurality of second connectors electrically coupled to the first  
21      connectors, wherein the second connectors extend from the thermal management unit  
22      for electrically coupling within a socket unit on a board. The thermal management  
23      unit may have a cap member attachable to a base portion in a sealed manner. The  
24      chamber within the thermal management unit may thermally manage an electronic  
25      device within via spray cooling, liquid immersion or other liquid cooling method.

26

27         There has thus been outlined, rather broadly, the more important features of the  
28      invention in order that the detailed description thereof may be better understood, and  
29      in order that the present contribution to the art may be better appreciated. There are

1 additional features of the invention that will be described hereinafter and that will form  
2 the subject matter of the claims appended hereto.

3

4 In this respect, before explaining at least one embodiment of the invention in  
5 detail, it is to be understood that the invention is not limited in its application to the  
6 details of construction and to the arrangements of the components set forth in the  
7 following description or illustrated in the drawings. The invention is capable of other  
8 embodiments and of being practiced and carried out in various ways. Also, it is to be  
9 understood that the phraseology and terminology employed herein are for the purpose  
10 of the description and should not be regarded as limiting.

11

12 A primary object of the present invention is to provide a liquid thermal  
13 management socket system that will overcome the shortcomings of the prior art  
14 devices.

15

16 A second object is to provide a liquid thermal management socket system for  
17 thermally managing an electronic device in a socket.

18

19 Another object is to provide a liquid thermal management socket system that  
20 can be utilized within air cooled sockets.

21

22 An additional object is to provide a liquid thermal management socket system  
23 that reduces the costs of utilizing liquid thermal management systems.

24

25 A further object is to provide a liquid thermal management socket system that  
26 does not require any modifications to a board or a socket.

27

28 Another object is to provide a liquid thermal management socket system that  
29 can be utilized with respect to various electronic device and socket coupler systems.

1

2        Other objects and advantages of the present invention will become obvious to the  
3        reader and it is intended that these objects and advantages are within the scope of the  
4        present invention.

5

6        To the accomplishment of the above and related objects, this invention may be  
7        embodied in the form illustrated in the accompanying drawings, attention being called  
8        to the fact, however, that the drawings are illustrative only, and that changes may be  
9        made in the specific construction illustrated and described within the scope of the  
10      appended claims.

1

## 2           **BRIEF DESCRIPTION OF THE DRAWINGS**

3

4       Various other objects, features and attendant advantages of the present  
5 invention will become fully appreciated as the same becomes better understood when  
6 considered in conjunction with the accompanying drawings, in which like reference  
7 characters designate the same or similar parts throughout the several views, and  
8 wherein:

9

10      FIG. 1a is a side view of a conventional socket unit with an electronic device  
11 coupled to the socket unit along with a heat sink.

12

13      FIG. 1b is an upper perspective view of a conventional socket unit attached to a  
14 circuit board.

15

16      FIG. 2 is an exploded upper perspective view of the present invention.

17

18      FIG. 3 is an exploded upper perspective view of the present invention with  
19 respect to a socket unit.

20

21      FIG. 4 is an upper perspective view of the present invention coupled to a socket  
22 unit (not seen) on a board.

23

24      FIG. 5 is a side view of the present invention coupled to a socket with an  
25 electronic device contained within.

26

27      FIG. 6 is an exploded side view of the present invention with respect to a  
28 socket unit.

29

1           FIG. 7 is a side cutaway view of the present invention utilized in a spray  
2 cooling application.

3

4           FIG. 8 is a side cutaway view of the present invention utilized in a liquid  
5 immersion application.

6

7           FIG. 9 is an upper perspective view of the base portion.

8

9           FIG. 10 is a side view of the base portion.

10

11          FIG. 11 is a side cutaway view of a device connector coupled within a first  
12 connector of the base portion.

13

14          FIG. 12 is a perspective view of the inner portion of the cap member containing  
15 a raised vapor management protrusion.

16

17          FIG. 13 is a perspective view of the inner portion of the cap member containing  
18 a raised fluid management protrusion.

19

20          FIG. 14 is a perspective view of another embodiment of the present invention  
21 wherein the base portion is directly mounted to the board.

22

23          FIG. 15 is a block diagram illustrating the fluid connection between the thermal  
24 management unit and a liquid thermal management system.

25

1

2                   **DETAILED DESCRIPTION OF THE INVENTION**

3

4       **A. Overview**

5           Turning now descriptively to the drawings, in which similar reference  
6          characters denote similar elements throughout the several views, FIGS. 3 through 15  
7          illustrate a liquid thermal management socket system **10**, which comprises a thermal  
8          management unit **20** having a chamber **50** for receiving one or more electronic devices  
9          **16**, a plurality of first connectors **32** within the thermal management unit **20** for  
10        electrically coupling with the electronic device **16**, and a plurality of second  
11        connectors **34** electrically coupled to the first connectors **32**, wherein the second  
12        connectors **34** extend from the thermal management unit **20** for electrically coupling  
13        within a socket unit **14** on a board **12**. The thermal management unit **20** may have a  
14        cap member **40** attachable to a base portion **30** in a sealed manner. The chamber **50**  
15        within the thermal management unit **20** may thermally manage an electronic device **16**  
16        within via spray cooling, liquid immersion or other liquid cooling method.

17

18       **B. Thermal Management Unit**

19           The thermal management unit **20** has a chamber **50** capable of receiving one or  
20        more electronic devices **16** (e.g. semiconductor chips, microprocessors, integrated  
21        circuit devices, power conversion devices, laser diodes, memory devices, etc.) as  
22        shown in Figures 7 and 8 of the drawings. The chamber **50** is fluidly connected to a  
23        liquid thermal management system **60** where a liquid coolant is applied (spray form,  
24        liquid immersion, etc.) to the electronic device **16** for thermally managing the  
25        electronic device **16**. Thermal management of the electronic device **16** may include  
26        maintaining, lowering or increasing the temperature of the electronic device **16**.

27

28           The thermal management unit **20** may be comprised of various structures  
29        capable of receiving and thermally managing one or more electronic devices **16**. For

1 example, the thermal management unit **20** could be comprised of a structure with an  
2 electronic device **16** permanently and non-removably positioned within the chamber  
3 **50**.

4

5 Figures 2 through 8 illustrate the usage of a base portion **30** and a cap member  
6 **40** removably attachable to the base portion **30**. The cap member **40** and the base  
7 portion **30** together form the chamber **50** where the electronic device **16** is positioned  
8 and thermally managed as shown in Figures 7 and 8 of the drawings. Additional  
9 discussion regarding the base portion **30** and the cap member **40** is below. It can be  
10 appreciated that various other structures may be utilized to construct the thermal  
11 management unit **20** other than shown in the figures and that the scope of the present  
12 invention should not be limited solely to the structure shown in the figures.

13

14 The thermal management unit **20** has a plurality of first connectors **32**  
15 positioned within the chamber **50** of the thermal management unit **20** as best illustrated  
16 in Figures 2, 3 and 9 of the drawings. The first connectors **32** may be electrically  
17 coupled to device connectors **19** of an electronic device **16** as shown in Figure 11 of  
18 the drawings. The first connectors **32** may be comprised of a pin grid array, a land grid  
19 array or a ball grid array or other connection structure capable of electrically  
20 communicating with an electronic device **16**.

21

22 The thermal management unit **20** has a plurality of second connectors **34** as best  
23 illustrated in Figures 6 and 10 of the drawings. Each of the second connectors **34** are  
24 electrically coupled to the first connectors **32** as best illustrated in Figure 11 of the  
25 drawings. The second connectors **34** extend exteriorly of the thermal management unit  
26 **20** for electrically coupling to at least one socket unit **14** or directly to a board **12**. The  
27 second connectors **34** may be comprised of a pin grid array, a land grid array or a ball  
28 grid array or other connection structure capable of electrically communicating with a  
29 board **12**.

1  
2       The second connectors **34** may correspond to the position of the first connectors  
3 **32** as shown in Figure 11 of the drawings. As further shown in Figure 11 of the  
4 drawings, the first connectors **32** may correspond to the position of the device  
5 connectors **19** of the electronic device **16**.

6

7       **C. Base Portion**

8       The thermal management unit **20** may be comprised of a combination base  
9 portion **30** and a cap member **40**. The base portion **30** comprises a floor **38** and a  
10 sidewall **39** forming a cavity as best illustrated in Figures 7 and 8 of the drawings. The  
11 cavity is sufficient in size and shape to receive at least one electronic device **16** as  
12 illustrated in Figures 3, 7 and 8 of the drawings. The base portion **30** may have  
13 various shapes and structures other than illustrated in the drawings.

14

15       A seal **36** is preferably positioned between the edge of the base portion **30** and  
16 the edge of the cap member **40** for sealing the chamber **50** between thereof as shown in  
17 Figures 7 and 8 of the drawings. Various seal **36** structures may be utilized to seal **36**  
18 the cap member **40** to the base portion **30** as can be appreciated.

19

20       The first connectors **32** and the second connectors **34** may be attached within  
21 the floor **38** as shown in Figure 11 of the drawings. The first connectors **32** and the  
22 second connectors **34** are each correspondingly coupled together as further shown in  
23 Figure 11.

24

25       Figures 2 and 9 illustrate the first connectors **32** as having a receptacle structure  
26 in a pin grid array for receiving device connectors **19** comprised of a pin structure or  
27 related structure. As stated previously, the first connectors **32** may also be comprised  
28 of various other structures (e.g. raised structures, etc.) capable of usage in a ball grid  
29 array, land grid array and other connection systems for electronic devices **16**. It can be

1 appreciated that the base portion **30** may include a retaining structure to retain the  
2 electronic device **16** within the base portion **30** such as but not limited to levers,  
3 fasteners and snaps.

4

5 Figures 6 and 10 of the drawings illustrate the second connectors **34** as having a  
6 pin structure for electrically coupling within socket receptacles **15** of a socket unit **14**.  
7 As stated previously, the second connectors **34** may also be comprised of various other  
8 structures (e.g. raised structures, etc.) capable of usage in a ball grid array, land grid  
9 array and other connection systems for electronic devices **16**.

10

11 Alternatively, the second connectors **34** may be electrically and physically  
12 coupled to a board **12** similar to the connection between a conventional socket unit **14**  
13 and a board **12**. Various connection methods may be utilized to connect the second  
14 connectors **34** directly to the board **12** such as but not limited to pins soldered into the  
15 board **12**, ball grid arrays and land grid arrays.

16

17 **D. Cap Member**

18 The cap member **40** is attachable in a sealed manner to the base portion **30** as  
19 illustrated in Figures 7 and 8 of the drawings. The cap member **40** may have various  
20 shapes and structures other than illustrated in the drawings.

21

22 The cap member **40** may be manufactured to dispense the liquid coolant  
23 (dielectric or non-dielectric) in either a spray cooling or liquid immersion application.  
24 Figures 7 and 12 illustrate utilizing the cap member **40** to dispense the liquid coolant  
25 in a spray cooling thermal management method. One or more nozzles **43** are  
26 positioned within the cap member **40** for spraying the coolant upon the electronic  
27 device **16**. The coolant may be atomized through the nozzles **43** as illustrated in U.S.  
28 Patent No. 5,860,602 and U.S. Patent No. 6,016,969. The thermally conditioned liquid  
29 coolant enters the inlet port **41** and is then dispensed into the chamber **50** upon the

1 electronic device **16** by the nozzles **43**, thermally conditions the electronic device **16**  
2 through liquid immersion and then exits through the exit port as waste coolant to be  
3 thermally conditioned by the liquid thermal management system **60**. As shown in  
4 Figure 12 of the drawings, a vapor management protrusion **46** may be utilized within  
5 the cap member **40** to manage the vapor generated within the chamber **50**. U.S. Patent  
6 No. 5,220,804 illustrates a suitable vapor management protrusion **46**. It can be  
7 appreciated that the inlet port **41** and the outlet port **42** may be positioned in various  
8 locations within the thermal management unit **20** such as also the base portion **30** and  
9 any combination thereof.

10

11 Figures 8 and 13 illustrate utilizing the cap member **40** to dispense the liquid  
12 coolant in a liquid immersion thermal management method. The thermally  
13 conditioned liquid coolant enters the inlet port **41** into the chamber **50**, thermally  
14 conditions the electronic device **16** through liquid immersion and then exits through  
15 the exit port. As shown in Figure 13, the cap member **40** may include a liquid  
16 management protrusion **48** that directs the liquid coolant in a path that reduces  
17 stagnation locations, such as a spiral pattern. It can be appreciated that the inlet port  
18 **41** and the outlet port **42** may be positioned in various locations within the thermal  
19 management unit **20** such as also the base portion **30** and any combination thereof.

20

21 Figure 8 illustrates the usage of an encapsulant **44** between the electronic  
22 device **16** and the base portion **30** to prevent a non-dielectric coolant from making  
23 contact with the first connectors **32** and the device connectors **19**. The encapsulant **44**  
24 can also be applied to surround and encase the first connectors **32** and the device  
25 connectors **19** (not shown).

26

27 **E. Liquid Thermal Management System**

28 The liquid thermal management system **60** is fluidly coupled to the chamber **50**  
29 for thermally managing an electronic device **16** by applying a liquid coolant to the

1 electronic device 16. The liquid coolant may be comprised of a dielectric or non-  
2 dielectric depending upon the electronic device 16 being thermally managed. The  
3 liquid thermal management system 60 may be comprised of spray cooling or liquid  
4 immersion.

5

6       Applicant hereby incorporates by reference the following U.S. patents: U.S. Patent  
7 No. 5,220,804 for a high heat flux evaporative cooling system; and U.S. Patent No.  
8 5,860,602 and U.S. Patent No. 6,016,969, each for a laminated array of pressure swirl  
9 atomizers. Although a laminated pressure swirl atomizer array is hereby incorporated by  
10 reference, the present invention is not limited to such an apparatus, in fact, many  
11 dispensing means are applicable to the present invention including but not limited to  
12 inserted atomizers, jet orifices and incremental sprayers.

13

14       The liquid thermal management systems 60 described herein include a pump,  
15 tubing, and the means for removing heat from a cooling fluid (e.g. heat exchanger). These  
16 components are necessary for the operation of a liquid thermal management system 60 but  
17 are widely understood in the field, and thus will not be covered in detail. Configurations  
18 and details of the above components are not necessary for one skilled in the art to  
19 understand the present invention.

20

21 ***F. Operation of Present Invention***

22       In use, the user may first electrically couple the thermal management unit 20  
23 within one or more socket units 14 within a board 12 (or directly to the board 12) and  
24 then position the electronic device 16 within the thermal management unit 20.  
25 Alternatively, the electronic device 16 may be first positioned within the thermal  
26 management unit 20 (sealed or non-sealed) and then later install the thermal  
27 management unit 20 to the board 12 which does not require further explanation.

28

1        When electrically coupling the thermal management unit **20** to a socket unit **14**,  
2    the user first aligns the second connectors **34** with the socket receptacles **15** of the  
3    socket unit **14** as shown in Figure 3 of the drawings. The user then presses the thermal  
4    management unit **20** so that the second connectors **34** are electrically coupled within  
5    the socket receptacles **15** of the socket unit **14**.

6

7        After the thermal management unit **20** is properly seated upon the socket unit  
8    **14**, the user then positions one or more electronic devices **16** directly above the first  
9    connectors **32** so that the device connectors **19** correspond to the first connectors **32** as  
10   shown in Figure 2 of the drawings. The user then presses the electronic device **16**  
11   downwardly into the base portion **30** of the thermal management unit **20** so that the  
12   device connectors **19** electrically couple with the first connectors **32** within the thermal  
13   management unit **20**. Various mechanical devices may be secured to maintain the  
14   electronic device **16** in the desired position. An encapsulant **44** may be added about  
15   the electronic device **16** and/or first connectors **32** and device connectors **19** if desired.

16

17       The cap member **40** is then attached in a sealed manner to the base portion **30**  
18   as shown in Figures 4 and 5 of the drawings. The thermal management unit **20** is then  
19   fluidly connected to the liquid thermal management system **60** as shown in Figure 15  
20   of the drawings.

21

22       The electronic device **16** may then be activated which generates heat (or heated  
23   liquid coolant may be first applied to the electronic device **16** to achieve a desired  
24   temperature). The electronic device **16** electrically communicates and is  
25   communicated to through the electrical connection created between the respective  
26   device connectors **19**, first connectors **32**, second connectors **34** and the socket  
27   receptacles **15**.

28

1       The thermally conditioned liquid coolant is applied to the electronic device **16**  
2 within the chamber **50**. After the liquid coolant is heated (or cooled) from the  
3 electronic device **16**, the waste coolant is then returned to the liquid thermal  
4 management system **60** for thermal conditioning and cleaning. It can be appreciated  
5 that the above method of use can be utilized in conjunction with pin grid arrays, ball  
6 grid arrays, land grid arrays and other connection systems.

7

8       As to a further discussion of the manner of usage and operation of the present  
9 invention, the same should be apparent from the above description. Accordingly, no  
10 further discussion relating to the manner of usage and operation will be provided.

11

12       With respect to the above description then, it is to be realized that the optimum  
13 dimensional relationships for the parts of the invention, to include variations in size,  
14 materials, shape, form, function and manner of operation, assembly and use, are  
15 deemed to be within the expertise of those skilled in the art, and all equivalent  
16 structural variations and relationships to those illustrated in the drawings and  
17 described in the specification are intended to be encompassed by the present invention.

18

19       Therefore, the foregoing is considered as illustrative only of the principles of  
20 the invention. Further, since numerous modifications and changes will readily occur to  
21 those skilled in the art, it is not desired to limit the invention to the exact construction  
22 and operation shown and described, and accordingly, all suitable modifications and  
23 equivalents may be resorted to, falling within the scope of the invention.